Chapter 3: Tissues in Action

How a Single Cell Becomes Skin, Bone, Sap and a Six-Hit Swing

Redeveloped Edition | Class 9 Science | IESC Series

Original NCERT content reimagined with everyday Indian life examples, creative AI-enhanced exercises, and interdisciplinary insights.

Opening Wonder

Look at your own forearm for a second. The skin covering it is tough enough to survive a fall on the gully-cricket pitch, yet soft enough to fold at your elbow thousands of times a day without cracking. Underneath, blood is quietly clotting shut a nick from yesterday's kitchen knife. Somewhere behind your eyes, an impulse just travelled from one neuron to the next faster than a UPI payment confirmation lights up your phone screen. And if your building has a garden, the hedge that the mali (gardener) trimmed last week is already growing bushier than before, not thinner.

None of this is one 'kind' of living material doing everything. Your body — and every plant on your street — is built from **teams of specialised cells**, each team drilled to do one job supremely well. Biologists call each such team a **tissue**.

In Chapter 2, you learnt that the cell is the basic unit of life, and that in a unicellular organism such as an amoeba, a single cell performs every function of life by itself. Multicellular organisms like plants and animals cannot rely on lone cells doing everything — instead, cells of similar structure that perform a similar function group together to form a tissue; different tissues combine to form organs; organs form organ systems; and organ systems form the entire organism. This layered organisation — cell → tissue → organ → organ system → organism — is what allows a body as complex as yours to run thousands of processes at once without chaos.

This specialisation is called **division of labour**, and it is one of nature's most efficient engineering decisions. Muscle tissue moves you; nervous tissue carries messages between one part of your body and another; in plants, xylem transports water and minerals upward while phloem transports food to wherever it is needed. This chapter asks the same three questions the original chapter opened with — why plant and animal tissues differ, how tissue structure is tied to function at every level of organisation, and why any of this matters for human welfare — and answers them one growing root tip, one heartbeat, and one joint at a time.

3.1 Why Are Plant and Animal Tissues Built Differently?

Most plants stay rooted in one place for their entire lives. They need a way to stay firm and upright without moving, so plant cells are wrapped in a rigid **cell**

wall that gives them strength and shape. Most animals, by contrast, move around (though a few, like sponges, do not). Without a rigid cell wall, animal cells can change shape easily — and that flexibility is exactly what makes bodies suitable for locomotion.

A second big difference is nutrition. Animals have tissues that digest food gathered from outside sources, while plants have tissues that trap sunlight and manufacture their own food through photosynthesis. Because their needs differ, plants and animals also evolved distinct tissues to transport water and food to different parts of the body, and different growth patterns, since the tissues responsible for growth differ in structure and function between the two kingdoms.

Everyday Connection: Your Building vs. Your Delivery Rider

Think of a Swiggy or Zomato delivery rider weaving through evening traffic, and compare that to the RCC (reinforced cement concrete) pillar holding up the building you live in. The pillar is engineered to stay exactly where it is for decades — rigid, load-bearing, never bending. The rider's body is engineered to twist, brake, lean into a turn and squeeze through a gap between two auto-rickshaws.

A plant is architecturally closer to the pillar: fixed in place, so its cells are reinforced with a stiff cell wall the way a pillar is reinforced with steel rods. An animal is architecturally closer to the rider: mobile, so its cells stay flexible with no rigid wall at all. Neither design is 'better' — each is precisely suited to whether the organism stays put or goes places.

Meet a Scientist: B. G. L. Swamy

B. G. L. Swamy was a renowned Indian botanist known for his contributions to plant morphology and anatomy — the very branch of biology this chapter draws from. His book *Hasuru Honnu* ('Green Gold'), written in Kannada, is a striking blend of science, satire and culture. It describes botanical excursions through the forests of the Western Ghats and is considered a treasure of plant descriptions, conservation practices, and botanical folklore and myths from the region. The book won the Kendra Sahitya Akademi Award in 1978.

Lesson: rigorous plant science and vivid regional storytelling are not opposites — Swamy's career shows they can be the same book.

3.2 Tissues for Growth in Plants — Meristematic Tissue

A seedling grows into a tall tree, roots push deeper into the soil, stems thicken with time, and grass reappears within days of being grazed or mowed. Plants grow in three distinct ways: an **increase in length** (height of stem, depth of roots), an **increase in girth** (thickness of stem), and **regrowth after cutting**

or grazing. Each of these requires actively dividing cells, together forming a tissue called **meristematic tissue**. There are three kinds — apical, lateral and intercalary — and each is responsible for one of the three growth patterns above.

3.2.1 Apical meristem — how do plants grow in length?

The growth zones located at the very tips of roots and shoots are called **apical meristems**. They contain cells that divide continuously and rapidly, and this is the only place from which a root or shoot actually lengthens.

Activity 3.1 — Redeveloped: Regrow an Onion on Your Kitchen Windowsill

Original book version: Two onion bulbs are placed in separate jars of water; on day 3, the root tips of one bulb are cut by about 1 cm; root growth is measured daily for both bulbs across seven days.

Everyday Version: You've probably seen the 'regrow your vegetables from kitchen scraps' trend on Instagram Reels — spring onion bulbs or leftover onions regrown in a glass of water on the kitchen windowsill. Let's turn that trend into a real experiment.

Take two identical onion bulbs (Jar A and Jar B) and place each in a glass jar filled with water so the base touches the water. Measure the root length of both on Day 1, 2 and 3. On Day 3, snip about 1 cm off the root tips of Jar B only, and continue measuring both jars daily through Day 7.

Record your readings in a table like this:

Jar	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
A							
B (tips cut on Day 3)							

You will find that roots in Jar A keep growing steadily in length across all seven days, while roots in Jar B stop growing almost as soon as their tips are removed. This shows that roots grow **only from their tips**, where cells divide continuously — you may recall observing mitosis in onion root tips in Chapter 2. Shoot tips behave the same way. Together, these growth zones at root and shoot tips are called apical meristems, and they are what let a plant grow taller and its roots grow deeper.

Pause and Ponder: Why do you think meristematic cells lack large vacuoles?

Everyday Connection: The Opposite of a Haircut

Here's a useful contrast, not a match. Your hair grows from the **root**, hidden beneath your scalp — which is why a haircut at the visible tip never slows down how fast your hair grows back; the growing zone was never touched. A

plant root works the opposite way: its growth zone, the apical meristem, sits right at the **tip**. That is exactly why nurseries and gardeners are trained to handle sapling roots and shoot tips with extreme care while transplanting — nick the tip, and you have cut off the one part of the root actually capable of extending it further, just like Jar B in the activity above.

3.2.2 Lateral meristem — how do plants grow in girth?

Stems of dicot plants (like mango or neem trees) not only grow in length but also increase steadily in diameter over the years. This happens because of an actively dividing ring of cells running around the circumference of the stem, called the **lateral meristem**. These cells divide and add new cells inside and outside in a concentric manner, increasing the stem's girth year after year.

If you have visited a timber yard or seen the cut trunk of a felled tree, you have likely noticed ring-like patterns on the exposed wood. These are **annual growth rings** — one ring is typically added per year. Wide rings usually mean a favourable growing year (good rainfall, warmth); narrow rings usually mean a harsher year (drought, cold). By counting these rings, scientists can estimate a tree's age and reconstruct the climatic conditions it lived through — a field called dendrochronology.

Everyday Connection: The Epoxy River Table and the Furniture Market

Walk into a home-décor store or scroll through an Indian carpentry page online and you will spot the trending 'epoxy river table' — a thick cross-section of a tree trunk, its natural growth rings polished and filled with coloured resin. Every ring in that slab is one year of the tree's life, laid down by its lateral meristem. A carpenter (mistri) reading those rings can often tell you roughly how old the tree was and whether it lived through a particularly dry or wet stretch of years — the same principle scientists use, just applied to your living room furniture instead of a research lab.

Worked Example — Redeveloped: Ageing the Teak Tree Behind the School Building

Original book version: A data table (Table 3.7) gives the age, stem diameter (DBH) and number of annual rings for a teak tree, to be plotted and interpreted.

Everyday Version: Suppose your school has an old teak tree in its compound, planted the year the school itself was founded. A forestry student measures its diameter at breast height (DBH) at different assumed ages and counts the rings on a similar felled tree nearby:

Age of tree (years)	Diameter at breast height (cm)	Number of annual rings
5	4	5
10	8	10
20	24	20
25	28	25
30	32	30
40	40	40

Plotting age on the x-axis against diameter and ring count on the y-axis produces two lines that track each other almost perfectly — the number of annual rings increases in step with age, and diameter grows roughly in proportion too (though the rate is not perfectly linear in real trees, since some years add thicker rings than others). This confirms that the girth of a stem and its ring count are both direct records of the activity of the **lateral meristem**, located in a ring around the stem's circumference — and that counting rings is a genuinely reliable way to estimate a tree's age.

3.2.3 Intercalary meristem — how do plants grow back after being cut?

What happens if the tip of a young stem is removed? Growth in length stops at that point, but new branches sprout from the **nodes** of the stem (a node is the point where a leaf or branch arises; the stem segment between two nodes is the **internode**). This regrowth happens because of the **intercalary meristem**, located at the base of an internode or just above a node.

Everyday Connection: Why a Durga Puja Pandal Never Runs Out of Bamboo

Every autumn, kilometres of bamboo scaffolding go up across Kolkata to build Durga Puja pandals, and bamboo is harvested year after year for scaffolding, furniture and paper across the North-East. The reason the bamboo supply keeps regenerating is the intercalary meristem sitting at each node of the culm (stem) — cut a bamboo stalk, and new shoots rise again from the nodes left behind, the same way a housing-society lawn regrows its blades within days of being mowed, or a garden hedge grows bushier every time it's trimmed.

Together, apical, lateral and intercalary meristems account for every way a plant grows — in length, in girth, and in branching after damage.

What makes a meristematic cell special?

Cells of meristematic tissue are small, with thin cell walls, a large and prominent nucleus, and dense cytoplasm packed with organelles. They are tightly packed with almost no intercellular space, and vacuoles are generally absent. These features together allow rapid, continuous cell division.

As new cells are produced, some remain meristematic, while others lose the ability to divide and instead change in structure and function to become **permanent tissue**, specialising for jobs such as support, transport or storage. This process — meristematic tissue becoming specialised and losing the ability to divide further — is called **differentiation**.

3.3 Permanent Tissues — Once a Cell Settles Into Its Job

If you examine a transverse section of a sunflower stem under a microscope, you will see several visibly different groups of cells — not one uniform mass. Each group is a permanent tissue, specialised for one function. Permanent tissues can be **simple** (built from only one type of cell) or **complex** (built from more than one type of cell working together).

(i) Protective tissue — the epidermis

The **epidermis** forms the outermost layer of the plant body: a tightly packed single layer of flat, rectangular cells that protects every part of the plant from mechanical injury, water loss, invading microorganisms, and harsh environmental conditions. Epidermal cells are covered by a waxy layer called the **cuticle**, which is especially thick in plants adapted to dry habitats, to cut down water loss during transpiration. Hair-like projections from epidermal cells form root hairs (which increase surface area for absorbing water and minerals) and, in leaves, the epidermis contains pores called **stomata**, which handle gaseous exchange and transpiration — the evaporation of water vapour that, in turn, creates the transpiration pull that helps draw water upward through the xylem and helps eliminate wastes from the plant body.

> **Everyday Connection: Your Epidermis Is a Screen Guard, Not a Sealed Case**
>
> A tempered-glass screen guard on your phone blocks scratches and moisture the way a plant cuticle blocks water loss and mechanical injury. But notice: your phone's case still has cut-outs for the camera, speaker and charging port — because a fully sealed phone would be useless. A plant's cuticle works the same way: it seals most of the surface, but stomata are deliberately left as controlled openings, because a plant that couldn't exchange gases at all would suffocate even while staying perfectly waterproof.

Pause and Ponder: Why is a thick cuticle on the epidermis an advantage for a plant living in a desert, but a disadvantage for a plant living underwater?

(ii) Supporting tissue — parenchyma, collenchyma and sclerenchyma

What keeps a plant upright? Why does a fresh twig bend while a dry one snaps? These jobs are handled by three types of simple permanent (supporting) tissue, each differing in structure.

a. Parenchyma: Living cells with thin walls, loosely packed with intercellular spaces. Parenchyma mainly stores food, but in green parts of the plant it also carries out photosynthesis. In aquatic plants, specialised parenchyma forms air spaces that help the plant float.

b. Collenchyma: Living cells with unevenly thickened corners, due to deposits of pectin (a chemical that behaves like flexible rubber). This tissue gives support while still allowing stems and tendrils to bend without breaking.

c. Sclerenchyma: Cells with thick walls due to lignin deposits, making them hard, strong and mostly dead. This tissue gives plants their woody strength and is found in stems, leaf veins, and hard coverings like coconut husk and walnut shell.

Everyday Connection: Pudina, Ganne ka Ras, and the Coir Mat by the Door

Snap a soft pudina (mint) or palak (spinach) stalk — it breaks cleanly, because it is mostly loosely packed parenchyma with very little reinforcement. Now bend a stick of sugarcane before it's crushed for ganne ka ras (sugarcane juice) — it flexes without snapping, thanks to the pectin-rich collenchyma just under its rind. Finally, look at a coir doormat woven from coconut husk fibre — an industry Kerala and Tamil Nadu have built for generations — and you are looking at pure sclerenchyma: dead, lignin-hardened cells so tough they survive years of muddy feet. Same plant kingdom, three completely different jobs, three completely different cell designs.

Pause and Ponder: Coconut husk fibres are hard and brittle, while coriander (dhaniya) leaf stalks are soft and flexible. Both are plant tissue — so what structural difference explains the contrast?

Ready to Go Beyond: The Bark on Your Chai Masala Shelf

As a stem ages, cells just below the epidermis regain the ability to divide, forming a lateral meristem called the **cork cambium**. It produces cork cells — dead, tightly packed, and impermeable to water and gases — which together form the **bark** of a tree. You almost certainly already own a piece of this tissue: cinnamon, the dalchini stick in your garam masala tin, is literally the dried inner bark of a Cinnamomum tree. Elsewhere in the world, the bark of the cork oak is peeled and shaped into wine-bottle stoppers and pinboards. Same tissue, wildly different jobs, depending on which tree it came from and what humans decided to do with it.

(iii) Conducting tissues — xylem and phloem

How does water reach the leaves of a 30-metre-tall tree? How does the food made in leaves reach the roots? Plants have specialised conducting tissues — **xylem** and **phloem** — together called **complex permanent tissues** because each is built from several different types of cells working as a unit.

Xylem transports water and minerals from the roots to the rest of the plant, and also provides mechanical strength. It consists of tracheids, vessels, xylem parenchyma and xylem fibres. Xylem parenchyma is the only living component; tracheids, vessels and xylem fibres are all sclerenchymatous (dead, thick-walled). Phloem, by contrast, is mostly made of living cells: sieve tubes (long tubular cells joined end to end through perforated walls, which transport food), companion cells (specialised parenchyma cells that regulate the loading and unloading of sugars into sieve tubes), phloem parenchyma (which stores food, resin, tannins and latex) and phloem fibres (sclerenchymatous cells that provide structural support to the sieve tubes).

Everyday Connection: Xylem Is Your Building's Overhead Tank Pipeline

In many Indian apartment buildings, a pump pushes water up to an overhead tank, and gravity-fed pipes then carry it down to every tap. Xylem does something even more remarkable without a pump: water is pulled upward purely by transpiration — the evaporation of water vapour from stomata creates a continuous 'pull' that drags the water column up through dead, hollow xylem cells all the way from root to leaf, floor after floor, against gravity, for free.

This is also why grafting works. When a farmer grafts a high-yield Alphonso or Dasheri mango branch (the scion) onto a hardy rootstock — a technique used across Indian mango orchards — the graft only succeeds if the xylem and phloem of the scion and rootstock physically reconnect. Without that vascular continuity, the scion cannot receive water from below or send food downward, and the graft fails.

Thread of Curiosity: How Does Water Climb a 30-Metre Coconut Tree?

Once water is absorbed by the roots, it must travel upward against gravity through xylem cells that are, remarkably, mostly dead. How do 'dead' xylem cells cooperate with living leaf cells to keep water moving? The living cells in the leaf keep transpiring — losing water vapour through stomata — which continuously pulls the next bit of water up the xylem column from below, the way sipping steadily from the top of a long straw draws liquid up from the bottom, even though the straw itself is not alive.

So far, we have studied plant tissues grouped by function — protection, support and conduction. In the plant body, they don't work in isolation; they are organised into larger groups called **tissue systems**: the **dermal tissue system** (the outer covering that protects and limits water loss), the **ground tissue**

system (the bulk of the plant body between dermal and vascular tissue, made of parenchyma, collenchyma and sclerenchyma), and the **vascular tissue system** (xylem and phloem together).

Pause and Ponder: What would happen if there were no stomata in the epidermis of the stem or leaves?

3.4 Animal Tissues — Four Teams, One Body

Like plants, animal cells also group together and specialise to perform different functions. Try this right now: blink your eyes quickly, clench and open your fist, take a deep breath, and touch something warm or cold. Which tissue helps you move? Which senses heat or cold? Which lets oxygen enter your blood? Which holds your body together so your skin doesn't simply fall off? The answers lie in the diversity of animal tissue, which is broadly grouped into four types: **epithelial, connective, muscular and nervous tissue**.

3.4.1 Epithelial tissue

Epithelial tissue forms the outer covering of the body (skin) and lines internal organs such as the mouth, lungs, blood vessels and intestine. It is made of closely packed cells with very little space between them — a structure that keeps germs out, reduces water loss, and still allows absorption, secretion and movement of substances where needed. Different epithelial tissues are structurally adapted for different jobs:

Function	Structure	Location in the body
Exchange: rapid diffusion of liquids and gases	Single layer of thin, flat cells	Lining of blood vessels and lungs
Protection: shields underlying tissue from injury, friction, microbes	Many layers of cells; outer cells flat and tightly packed	Skin, mouth and oesophagus
Secretion: producing and releasing mucus, enzymes, hormones, sweat, saliva	Cells specialised to secrete; may be cuboidal or columnar	Salivary glands, sweat glands, stomach lining
Sensory: smell, taste, sound, balance	Specialised receptor cells with hair-like cilia	Nostrils, taste buds, inner ear
Absorption: efficient uptake of nutrients and water	Single layer of tall, pillar-like cells, often with hair-like structures	Lining of the small intestine

Everyday Connection: Why Delhi's Smog Season Hits Your

Lungs So Fast

The exchange epithelium lining your lungs is only a single layer of thin, flat cells — deliberately thin, because gases need to diffuse across it quickly for you to breathe efficiently. That same thinness is exactly why air pollution during Delhi-NCR's winter smog season, or firecracker smoke around Diwali, affects lungs so fast: fine particulate matter (PM2.5) crosses that thin exchange surface almost as easily as oxygen does. Compare this to the protective epithelium of your skin, which is many layers thick precisely because its job is to block things out, not let them through — which is also why a scrape heals from the surface inward instead of exposing deeper tissue immediately.

3.4.2 Connective tissue — how are parts of the body connected?

Blood connects different parts of the body by transporting nutrients, gases and hormones. Bones connect and support the body from head to toe. A tissue that connects and supports other tissues is called **connective tissue**. Blood and bone are both connective tissues, yet one is fluid and the other is hard — the difference lies in the **matrix**, which is watery, soft and jelly-like in blood, but hard, solid and rigid in bone.

Activity 3.2 — Redeveloped: Reading Your Own Body's Signals

Original book version: A table of everyday experiences (a cut on the skin, a skin infection, exercising) is matched against biological observations.

Everyday Version: Think of ordinary moments from your week — nicking your finger while cutting vegetables for dinner, getting a mosquito-bite infection during monsoon, or sprinting the last over of a gully-cricket match — and match them to what's really happening inside:

Everyday experience	What you observe	What's really happening
A small cut while chopping vegetables	Red blood oozes out, then a clot forms	Platelets trigger clotting at the injury site
A skin infection or mosquito bite gets inflamed	The area turns red, slightly swollen; you may run a fever	White Blood Cells (WBCs) gather at the site, causing inflammation and sometimes pus
Sprinting during a gully-cricket over	You breathe faster; your face turns red	Muscles demand more oxygen, so breathing and blood flow both increase

The red colour of blood comes from **haemoglobin**, an iron-rich protein in Red Blood Cells (RBCs), which live for about four months and are continuously replaced. Platelets handle clotting; White Blood Cells (WBCs) fight infection.

Everyday Connection: Blood Donation Camps and the Iron in Your Thali

Schools and colleges across India regularly host blood donation camps, and doctors routinely check hameoglobin levels before you're allowed to donate — because low iron (common among Indian teenagers, especially girls) means fewer haemoglobin-carrying RBCs. Iron-rich foods like spinach (palak), jaggery (gud) and legumes help maintain healthy haemoglobin levels, which is also why thalassemia and anaemia awareness drives are common in Indian schools: both conditions are ultimately about this one connective tissue — blood — and its ability to carry oxygen.

Ready to Go Beyond: When Bone Marrow Itself Becomes the Cure

Stem cells in bone marrow can divide and produce new blood cells throughout your life. In a bone marrow transplant, stem cells from a healthy, matched donor are given to a patient suffering from blood cancers such as leukaemia, or blood disorders such as thalassemia. Hospitals such as Tata Memorial Centre in Mumbai and CMC Vellore perform such transplants in India, and stem-cell donor registries work to match patients with willing donors. It is a striking example of connective tissue itself — blood, made fresh by marrow — being used as medicine.

Activity 3.3 — Redeveloped: Feel Your Own Connective Tissue

Try each action below on yourself right now, and match what you feel to the connective tissue responsible:

Action	What you feel	Function	Connective tissue
Touch your elbow gently	A hard, rigid structure	Strength, support, protection	Bone
Press and fold your ear, or gently press your nose	A soft structure that springs back into shape	Flexibility and shock-absorbing cushioning	Cartilage
Wiggle your fingers while touching your forearm	Movement in the forearm even though the fingers	Connects muscle to bone, producing	Tendon

Action	What you feel	Function	Connective tissue
	are far away	movement	
Sit and raise your leg from the knee until it stops	The joint halts at a fixed limit	Connects bone to bone; limits movement, prevents dislocation	Ligament

Bone has a rigid matrix rich in calcium and phosphorus compounds; cartilage has a soft, jelly-like matrix that cushions and flexes. This is also why an ear or nose piercing heals without the structure collapsing — cartilage keeps its shape without being brittle, which is exactly why anterior cruciate ligament (ACL) and cartilage injuries are so common — and so slow to heal — among young cricketers, footballers and badminton players who twist a knee suddenly.

3.4.3 Muscular tissue — can we control movement in our body?

Some movements are under conscious control — running, writing, playing a cover drive — and are called **voluntary movements**, carried out by **skeletal muscle**, attached to the skeleton. Skeletal muscle fibres are long, cylindrical, unbranched, multinucleate (many nuclei) and striated (showing light and dark bands).

Other movements happen automatically, without conscious control — food moving through the intestine, the heart beating — and are called **involuntary movements**. These are carried out by **smooth muscle** (found in organs like the stomach and intestine; spindle-shaped cells, single nucleus, unstriated, producing slow, continuous movement) and by **cardiac muscle** (found only in the heart; cylindrical, branched fibres with a single nucleus and faint striations, contracting rhythmically and tirelessly for a lifetime without fatigue).

Everyday Connection: The Super Over

Picture the last ball of a T20 Super Over. Your heart is hammering — that's cardiac muscle, involuntary, contracting faster because your nervous system has told it to, without you ever deciding to speed it up. At the same time, you consciously clench your fist in tension — that's skeletal muscle, voluntary, entirely under your control. An hour later, your body is quietly digesting the samosas you ate at the interval — smooth muscle, involuntary, slow and steady, moving food along your intestine without you noticing at all. Three tissue types, three different jobs, all firing in the same ten minutes.

3.4.4 Nervous tissue — how does the body sense, communicate and respond?

Notice how quickly you pull your hand away from something hot, or how easily you recall the lyrics of a song you learned years ago. These are the work of **nervous tissue**, the body's control and coordination network. The brain acts as the control centre, coordinating activity, memory and responses throughout the body; muscles cannot function independently and instead receive instructions from nervous tissue — for instance, during exercise, the brain signals the heart to beat faster to meet rising oxygen demand.

The cells of nervous tissue are called **neurons**, specialised to receive, process and transmit messages. Each neuron has three main parts: the **cell body** (contains the nucleus, controls cell activities), **dendrites** (receive signals from other neurons), and an **axon** (a long fibre carrying messages away from the cell body, ending in axon terminals that pass the message on to the next cell).

Everyday Connection: The Hot Tawa Reflex

Accidentally brush your hand against a hot tawa or the side of a pressure cooker, and your hand snaps back before you've even consciously registered the pain — that split-second reaction is a reflex arc racing through nervous tissue, from receptor to spinal cord to muscle, deliberately built to bypass the slower route through your brain entirely. It's the same reflex that makes you catch a phone the instant it slips off the arm of the sofa, often before you've had time to 'think' about catching it at all.

Meet a Scientist: Santiago Ramón y Cajal

The Spanish histologist Santiago Ramón y Cajal used painstaking microscope work and silver-staining techniques to show, against the prevailing view of his time, that the nervous system is built of individual, separate nerve cells — neurons — rather than one continuously fused network. This became known as the 'neuron doctrine' and remains the foundation of modern neuroscience. He shared the 1906 Nobel Prize in Physiology or Medicine with Camillo Golgi for their work on the structure of the nervous system.

3.5 The Musculoskeletal System — Engineering of Movement

The musculoskeletal system is built from bones, muscles, joints, cartilage, tendons and ligaments working together. It lets you stand upright, move, maintain posture and protects delicate internal organs — all under the control of the nervous system. Muscles pull on bones to produce movement; they are attached to bones by tough, flexible bands called **tendons**. When a muscle contracts, the tendon transmits that force to the bone, producing movement at a

joint. On average, the adult human skeleton makes up about 12–15% of body weight, though this varies with age, gender and body composition.

Activity 3.4 — Redeveloped: What Percentage of You Is Bone and Muscle?

Original book version: Step on a weighing scale, look up average bone and muscle mass percentages, and calculate estimated bone and muscle weight.

Everyday Version: Fitness tracking is everywhere now — smart scales, fitness bands, gym apps — so let's use that same instinct scientifically.

1. Step on a weighing scale and record your total body weight.

2. Use trusted health references to find average bone and muscle mass percentages for your age and gender. As general reference points: adult males average about 40–50% muscle mass, adult females about 30–40%, while bone mass averages roughly 12–15% of body weight for all adults (these can vary by individual body type).

3. Multiply your total body weight by each percentage to estimate your bone weight and muscle weight.

4. Compare your estimated bone and muscle weight with your total body weight, then compare your numbers with your classmates' and calculate a class average.

Discuss: why do bone and muscle mass differ between individuals, and how does each contribute to total body weight?

3.5.1 Types of joints

A **joint** is a junction between two or more bones. Joints allow movement, but cannot move bones on their own — muscles do that work, pulling on bones through tendons. Different joints allow different kinds of movement, depending on how the bone ends are shaped.

Ball and socket joint: The rounded top of the upper arm bone fits into a shallow hollow of the shoulder bone, allowing forward, backward, sideways and circular movement — this is what lets a fast bowler's arm complete a full windmill rotation, or a badminton player smash overhead.

Hinge joint: The elbow and knee bend and straighten in one direction only, like a door hinge — the movement you feel in a football tackle or a deep squat.

Pivot joint: The skull connects to the backbone through a pivot joint, letting the head turn side to side like a doorknob turning in its socket — try shaking your head 'no' and feel the movement at the back of your neck.

Fixed joint: The flat bones of the skull are joined by fixed joints that do not move at all, keeping the brain, eyes and ears safely protected even as the rest of the body moves.

Everyday Connection: Freeze-Frame a Dance Pose

Look at any photograph of a classical or folk dance performance — Bharatanatyam, Kathak, Bhangra, or a Kabaddi raid mid-dive. Every striking pose is really a snapshot of several joints working at their extremes at once: a ball-and-socket shoulder flung wide, a hinge knee bent low, a pivot neck turned sharply to one side. Choose one such pose you know well and try to name, joint by joint, exactly which type is doing the work, and what movement each one allows.

3.6 Skeletal System — The Living Framework

The **skeletal system** is a framework of bones that provides strength and protects delicate internal organs. It includes the skull, the vertebral column and the rib cage. From the base of the skull, a flexible column called the **backbone** or **vertebral column** (spine) extends downward, made of a series of small bones called vertebrae, supporting the body and letting it stand upright. Between each vertebra sits a cartilage disc, cushioning the load and allowing enough flexibility to bend and twist without injuring the spinal cord inside.

The 12 pairs of ribs you can feel under your chest form the **rib cage**, a protective enclosure for organs as vital as the heart and lungs. The ribs attach to the spine at the back and to the sternum (breastbone) at the front, joined by flexible cartilage — this flexibility is what lets the rib cage expand and contract during breathing, changing the volume of the chest cavity so air can move in and out of the lungs. This is also why a rib injury makes even ordinary breathing painful.

Bridging Science and Society: Yoga and the Musculoskeletal System

Yoga, described in ancient Indian texts, combines physical postures, breathing and meditation. Research shows it improves flexibility, posture and breathing, reduces stress, and helps prevent lifestyle diseases — which is why 21 June is observed worldwide as International Yoga Day. If your school holds a morning Surya Namaskar session, notice how the sequence deliberately cycles through almost every joint type you've just studied: the shoulder's ball-and-socket reaching overhead, the knee's hinge bending into a lunge, the spine's flexible column arching and folding. Maintaining correct posture, balanced nutrition, regular exercise and yoga together keep bones strong, muscles fit, and joints flexible.

3.7 One Cell, Whole Organism — Totipotency and Modern Biotechnology

In 1958, plant physiologist F. C. Steward demonstrated something extraordinary: even single, fully mature cells taken from the vascular phloem of a carrot retain the ability to regenerate an entire plant. He and his team grew phloem cells in a nutrient medium containing simple sugars and hormones under carefully controlled conditions. The cells first **dedifferentiated** (regained the ability to divide) to form a mass of unspecialised cells, which then divided further and **redifferentiated** into roots, shoot, and eventually a complete plant.

This showed that some mature plant cells can undifferentiate, divide, and redifferentiate into a whole new organism under the right conditions — a property called **totipotency**, and such cells are called **totipotent cells**. This is comparable to the ability of a zygote (fertilised egg) to divide and differentiate into an entire organism.

Worked Example — Redeveloped: The One Carrot Cell That Became Many Carrots

Original book version: Table 3.6 gives the effect of light, air and nutrient medium combinations on the fresh weight of cultured carrot phloem cells.

Everyday Version: Imagine you are running Steward's experiment yourself in a school biotech lab, testing three different growing conditions for the same carrot phloem cells:

Condition (light / air)	Composition of nutrient medium	Change in fresh weight of cells
No light, no air movement	Solid medium + nutrients	Reduced
No light, air movement (stirred)	Liquid medium + nutrients	20% increase
Light, no air movement	Liquid medium + nutrients	Reduced

Only the stirred liquid medium with nutrients (movement plus nutrients, without a hard requirement for light) produced real growth — a clue that these dedifferentiated cells behave less like ordinary green, photosynthesising plant cells and more like an actively dividing, nutrient-dependent mass, similar in spirit to meristematic tissue. Think about: which combination gave the highest and lowest biomass, and why? Would you expect the same result if you cultured animal cells instead of carrot cells? And what commercial uses can you think of for cell cultures like this one?

Everyday Connection: The Banana Plantlet Industry

Steward's discovery wasn't just a lab curiosity — it built an entire industry. Tissue-culture labs in Maharashtra (Jain Irrigation being one of the world's largest producers) now grow millions of disease-free banana plantlets a year from tiny fragments of plant tissue, exactly the way Steward's carrot fragments grew into whole carrot plants. Farmers across India plant these lab-raised, genetically identical, disease-free plantlets instead of traditional suckers, because tissue culture guarantees uniform, healthy crops at a scale that couldn't happen from natural regeneration alone.

□□ Meet the Scientists: Sipra Guha Mukherjee and S. C. Maheshwari

Working together, Indian scientists Sipra Guha Mukherjee and S. C. Maheshwari made a breakthrough discovery in plant tissue culture: developing a complete plant through anther culture — growing pollen-bearing anther tissue on an artificial nutrient medium under controlled laboratory conditions. Their pioneering work contributed significantly to crop improvement and modern agriculture, and remains a landmark in Indian plant biotechnology.

□ Bridging Science and Society: The Bacterium That Became a Genetic Engineering Tool

Plant pathologists have long studied crown gall disease, in which tumour-like swellings develop on plant stems due to uncontrolled cell division, caused by the bacterium *Agrobacterium tumefaciens*. Rather than only trying to cure the disease, scientists studied how this bacterium naturally transfers its own genetic material into plant cells — and turned that natural ability into a tool. Agrobacterium-mediated gene transfer is now widely used in plant tissue culture and genetic engineering to introduce useful genes into crops, including Bt cotton grown across Maharashtra, Gujarat and Punjab, and various disease-resistant crop varieties. Genetically modified crops remain a genuinely debated topic in Indian agriculture and policy — a good example of how the same biological discovery can carry real social, economic and ethical weight.

Chapter Summary

Concept	Core idea	Everyday example
Meristematic tissue	Actively dividing cells that drive plant growth	A root tip growing in a windowsill onion jar

Concept	Core idea	Everyday example
Apical meristem	Growth zone at root/shoot tips increases length	Cutting a root tip stops that root's growth
Lateral meristem	Ring of dividing cells increases stem girth	Annual growth rings in an epoxy river table
Intercalary meristem	Growth zone at nodes allows regrowth after cutting	Bamboo regrowing after a Durga Puja pandal harvest
Simple permanent tissue	One cell type; parenchyma, collenchyma, sclerenchyma give storage, flexibility or strength	Soft pudina stem vs. tough coir doormat
Complex permanent tissue	Xylem and phloem, each built of several cell types, transport water and food	An overhead water tank's pipeline vs. a mango graft
Differentiation & totipotency	Meristematic cells specialise (differentiate); some mature cells can reverse this and regrow a whole organism	Banana plantlets grown by the millions from tissue culture
Epithelial tissue	Closely packed cells protecting, lining, secreting, sensing or absorbing	Thin lung lining vs. thick, protective skin
Connective tissue	Connects and supports organs; matrix ranges from fluid to rigid	Blood carrying oxygen; bone holding you upright
Muscular tissue	Skeletal (voluntary), smooth (involuntary, slow) and cardiac (involuntary, tireless)	Clenched fist vs. racing heart in a Super Over
Nervous tissue	Neurons receive, process and transmit signals for control and coordination	Snatching your hand off a hot tawa
Joints	Ball-and-socket, hinge, pivot and fixed joints allow different kinds of movement	A bowler's shoulder vs. a locked skull suture
Musculoskeletal system	Bones, muscles, tendons and ligaments coordinated by the nervous system	Surya Namaskar cycling through every joint type

Revise, Reflect, Refine — Exercises

Basic Recall

1. What special features of meristematic cells — wall thickness, presence of vacuoles, size of nucleus, density of cytoplasm — allow them to divide again and again?

2. List the four types of animal tissue and give one real example of where each is found in your own body.

3. State one structural difference each between: (a) xylem and phloem, (b) bone and cartilage, and (c) skeletal and cardiac muscle.

Apply & Think

4. Your tulsi (basil) plant on the balcony has had its growing tip nibbled off by a squirrel. Using what you know about the apical meristem, predict what will happen to the plant's height and its branching pattern over the next month.

5. During a nail-biting Super Over, your heart rate shoots up without you ever deciding it should, while you can consciously choose to clench your fist. Explain this difference using the muscle tissue types you studied, and explain why cardiac muscle can keep contracting for decades without fatigue.

6. Evaluate this Assertion-Reason pair: Assertion — 'Epithelium lining the lungs is many layers thick because thicker layers give better protection during a smog spike.' Reason — 'A single thin layer would let pollutants and gases diffuse in too fast.' Are the Assertion and Reason each true? Does the Reason correctly explain the Assertion? Justify your answer using what you know about lung epithelium.

Creative Design Challenges

7. The Sugarcane Cutting Investigation: Design an experiment — like Sohan's sugarcane cuttings in the original chapter — to compare regrowth from different parts of a mint (pudina) or sugarcane stem cutting. State your hypothesis, the variables you would keep constant, and exactly what you would measure to know whether regrowth succeeded.

8. Coconut Husk vs. Banana Leaf: A Chennai startup wants an eco-friendly packaging line — tough coir mats from coconut husk fibre on one side, and soft, biodegradable banana-leaf food plates on the other. Using tissue structure, explain why coir is tough and fibrous while banana leaf is soft and pliable, and why you cannot simply swap the tissue used for one product into the other.

9. The Debarked Tree Case File: A stray elephant strips the bark off a large neem tree at the edge of a village while feeding on the nutrient-rich bark. Write a short 'damage report' predicting which functions of the tree are affected immediately, which would only fail if the damage went deeper, and what the forest department should watch for over the following months.

10. AI Creative Spark — Biomimicry Challenge: Indian researchers increasingly design materials 'inspired by nature' (biomimicry). Propose a new water-filtration material or structure inspired by the architecture of xylem vessels (tiny, one-way tubes) or phloem sieve tubes. Describe how your design would work and exactly what natural feature you are copying.

🚀 Journey Beyond — Going Deeper

Challenge A: The Sports Injury Interview

Talk to a physiotherapist, sports coach or doctor about common ligament and cartilage injuries among young cricketers, footballers or badminton players. Ask which tissue is damaged in each case, how recovery typically works, and what changes in warm-up routine or diet are recommended to prevent them. Write up your findings as a one-page brief.

Challenge B: Growth-Ring Detective

Visit a local carpenter (mistri), timber yard or furniture market and ask to see a cut tree cross-section (or look up an 'epoxy river table' online if none is available nearby). Count the rings, estimate the tree's age, and note whether any rings look unusually narrow or wide. Research what climatic event — a drought year, an exceptionally good monsoon — in your region might explain the pattern you find.

Challenge C: The Quest Continues

If a single carrot phloem cell can regrow an entire carrot plant, could a single animal cell one day regrow a whole animal? Research real examples such as axolotl limb regeneration or stem-cell-based organ research, and write about what makes plant cells so much more totipotent than most animal cells — and what ethical questions would arise if cloning an entire animal from a single cell ever became cheap and easy.

Happy Exploring! Every callus on a cricketer's palm, every ring inside a tree trunk, and every silent nerve impulse racing through you right now is tissue in action — structure and function, working as one. 🌱🔬